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BULLETIN 262 JULY, 1917

THE CHANGE OF MILK FLOW WITH AGE, AS DETERMINED FROM THE SEVEN DAY RECORDS OF JERSEY COWS.

This Bulletin contains the results of a study of the milk flow of Jersey cows as affected by age. It shows that the milk flow change follows a definite logarithmic curve and that the maximum production is reached when the cow is between eight and nine years of age.

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BULLETIN 262

THE CHANGE OF MILK FLOW WITH AGE, AS DETERMINED FROM SEVEN DAY RECORDS OF JERSEY COWS.[1]

By Raymond Pearl and S. W. Patterson.

From the time of the earliest domestication of cattle it must have been realized that age was a factor influencing milk production. It is well known among dairymen and breeders that, other conditions being the same, a cow will produce more in a given length of time during her second lactation period than for the same time during her first period. She will produce more her third lactation period than her second; and so on until she reaches mature form, or the age for maximum production. She remains in this mature form for a few years; then each succeeding lactation period decreases in the rate of milk flow.

Opinions differ somewhat as to the average age at which a cow reaches mature form and as to the rate of increase with which she approaches that form. The general belief is that mature form is reached by the fifth year and that the curve representing the variation in milk flow by lactation periods up to that time is a straight line.

This latter opinion is evidenced by the requirements for advanced registry in the Ayrshire Breeders' Association rules—the only Association which has a milk requirement for advanced registry entry. Since the variation in the average percentage of butter fat in the total milk in different lactation periods is slight, the above opinion is substantially concurred in by the entry requirements, which are based on butter fat, in the rules of the other three dairy breeders' associations. The four associations are alike in fixing mature form at five years of age and in allowing nothing for decrease in productivity due to very advanced age.

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[1]Papers from the Biological Laboratory of the Maine Agr. Exp. Stat. No. 117.

Is this opinion right? Is this curve for changing rate of location due to age, correct in the form implied by advanced registry rules?

The purpose of this paper is to answer this question so far as concerns American Jersey cattle seven-day records. It is to ascertain from the data furnished by the seven day milk records in the book "Jersey Sires with their Tested Daughters"[2] first, the degree of correlation between age and milk production, second, the true curve for production at various ages for the seven day records of the Jersey breed, and then third, from these figures to determine the age correction for the seven day records so that they may be reduced to a common basis for comparison in future studies of the inheritance of milk production in the Jersey breed.

The character of the statistics in this volume—"Jersey Sires with their Tested Daughters"—is varied. About 90 per cent of them are taken from the private records of the earlier Jersey breeders, and 10 per cent are authenticated; that is each one of these latter was supervised by a representative from the office of the American Jersey Cattle Club, or by one from the office of the Agricultural Experiment Station in the State in which the test was performed in the same way that Advanced Registry tests are supervised today.

Though unauthenticated there is every reason to believe that the milk reports are true accounts of actual production, because butter was the part of the milk which the breeders wished to produce. To obtain this butter fat content of the milk it had to be skimmed and the cream churned as at that time the Babcock Test was not in general use. Consequently if there was any fraudulent work done, the incentive for it was in the making of the butter and not in the weighing of the milk produced. This idea is substantiated by the fact that no abnormally high averages of milk production for the different ages appear upon analysis of the records.

All the seven day tests in the volume cited, for which milk records were given, were the ones on which this paper is based, the total number used being 5821.

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[2]"Jersey Sires and their Tested Daughters". Published by American Jersey Cattle Club, New York, 1909.

Since these tests are arranged in the book alphabetically according to the names of the sires they give no comprehensive idea concerning the degree of relationship between the attributes age and weekly milk production. They were hence rearranged or classified in a table of double-entry or correlation.

In the arrangement of the table, age was chosen as ordinate and production as abscissa. The range of production was found by inspection of the data to be from 91 lbs., the record of Julia Landseer A. J. C. C. 56268, to 471 lbs. the record of Jimp A. J. C. C. 86488, or a range of 380 lbs. Obviously this is too large a range on which to use as a class unit a production of 1 lb., so 15 lbs. was chosen as this unit. For similar reasons as the range of age was from 1 year 4 months, the age for the test of Alexea Riotress King A. J. C. C. 176723 to 18 years 6 months, the age for the test of Jersey A. J. C. C. 3260, a class unit of 6 months was taken for the grouping of the cows—the first group being from 1 year to less than 1 year 6 months, etc., to 18 years 6 months and less than 19 years, or a total of 36 intervals.

The resulting correlation table is exhibited in Table 1.

By observation it is easily seen that there is a distinct variation in production with changing age. The correlation coefficient in this case is $r = .1925 \pm .0085$.

In view of the extreme skewness of the regression in this case, as will presently appear, no particular significance attaches to the correlation coefficient as such. Inasmuch as we are interested in the present connection only with the form of the regression curve we shall not develop further the purely correlational side of the matter.

The next step is to determine the curve of mean production with changing age. This was done by first plotting as one coördinate the mid-point of each age array, and as the other coördinate the mean production of the corresponding array. The resulting line is shown in Figure 7.

Table 1.

Correlation surface for the variables age and milk production in 7 days.

Jersey cattle.

Age	Milk 85—99	100—114	115—129	130—144	145—159	160—174	175—189	190—204	205—219	220—234	235—249	250—264	265—279	280—294	295—309	310—324	325—339	340—354	355—369	370—384	385—399	400—414	415—429	430—444	445—459	460—474	Totals
1:0—1:5	1	3	2	3	4	4	3	7	1	8	1	2	1				1										2
1:6—1:11		4	9	10	19	14	26	40	8	50	21	19	11	3	1		1	1		1							47
2:0—2:5		1	6	8	15	25	22	47	44	98	75	67	42	24	4	14	42	2	4								274
2:6—2:11		1	4	9	14	19	28	50	82	92	91	52	45	27	19	14	2	2	1								316
3:0—3:5		1	1	3	12	13	19	45	59	92	59	88	59	35	36	14	7	2	1	1	1						550
3:6—3:11		2	1	5	9	14	23	46	97	113	98	62	66	59	29	35	9	6	2			1					512
4:0—4:5				2	8	12	24	46	61	74	92	88	42	46	27	20	9	8	4		1						708
4:6—4:11			1	2	7	7	15	33	54	78	80	88	51	51	27	27	8	4	4								537
5:0—5:5		2	3	2	6	9	18	25	36	45	53	61	38	32	26	13	8	9	3	1		1					553
5:6—5:11		1		2	5	9	16	23	41	57	55	51	47	44	32	10	9	7	2	2	2	1	1				384
6:0—6:5		1	3		4	4	9	20	30	37	31	44	43	28	14	9	4	3	1	4	1	4	1				416
6:6—6:11				1	4	10	9	14	26	31	41	43	33	22	14	12	10	3	5	4	1	1	1				279
7:0—7:5					1	3	4	10	16	23	24	26	16	12	13	13	3	3	4	2	1	1	1				296
7:6—7:11				2	2	6	8	12	18	26	19	13	22	14	10	11	1	4	2	3	1	1	1				190
8:0—8:5					3	2	7	6	14	14	16	10	13	17	6	6	2	1	1	1	1	1	1				170
8:6—8:11				1		3	4	6	10	14	15	15	6	10	8	8	1	1	1	1	1	1	1				123
9:0—9:5			1			3	5	6	7	11	17	10	8	8	8	4	2	1	1	1	1	1	1				110
9:6—9:11		1			2	3	2	6	6	11	13	11	6	5	2	1	1	1	1			1	1				96
10:0—10:5			1				1	2	1	7	5	5	4	6	5	2	1	1									63
10:6—10:11		1		1		1	1	1	4	6	3	2	4	4	2	1	3	1			1	1					39
11:0—11:5		1			3	1	1	2	4	4	6	4	3	11						1						1	56
11:6—11:11							2	4	5	4	5	10	1	3	1		1	3									27
12:0—12:5					1			1	1	4	2	1	1	1	1		1	1	2								20
12:6—12:11						1	1	1	1	4	3		1	1			2										7
13:0—13:5							1		1	3	1	1		1	1	2											10
13:5—13:11		1								1	1	2	2		1					1							9
14:0—14:5								3	1	1	1	1			1												8
14:6—14:11				1								1		1													5
15:0—15:5			1							1	2	1	1														4
15:6—15:11											2																2
16:0—16:5					1				1			1															3
16:6—16:11						1				1	1		1														4
17:0—17:5																											—
17:6—17:11																											—
18:0—18:5									1																		—
18:6—18:11																											1
Totals	1	20	33	57	123	161	252	461	689	848	822	693	515	443	286	198	82	58	32	18	9	11	6	2	—	1	5821

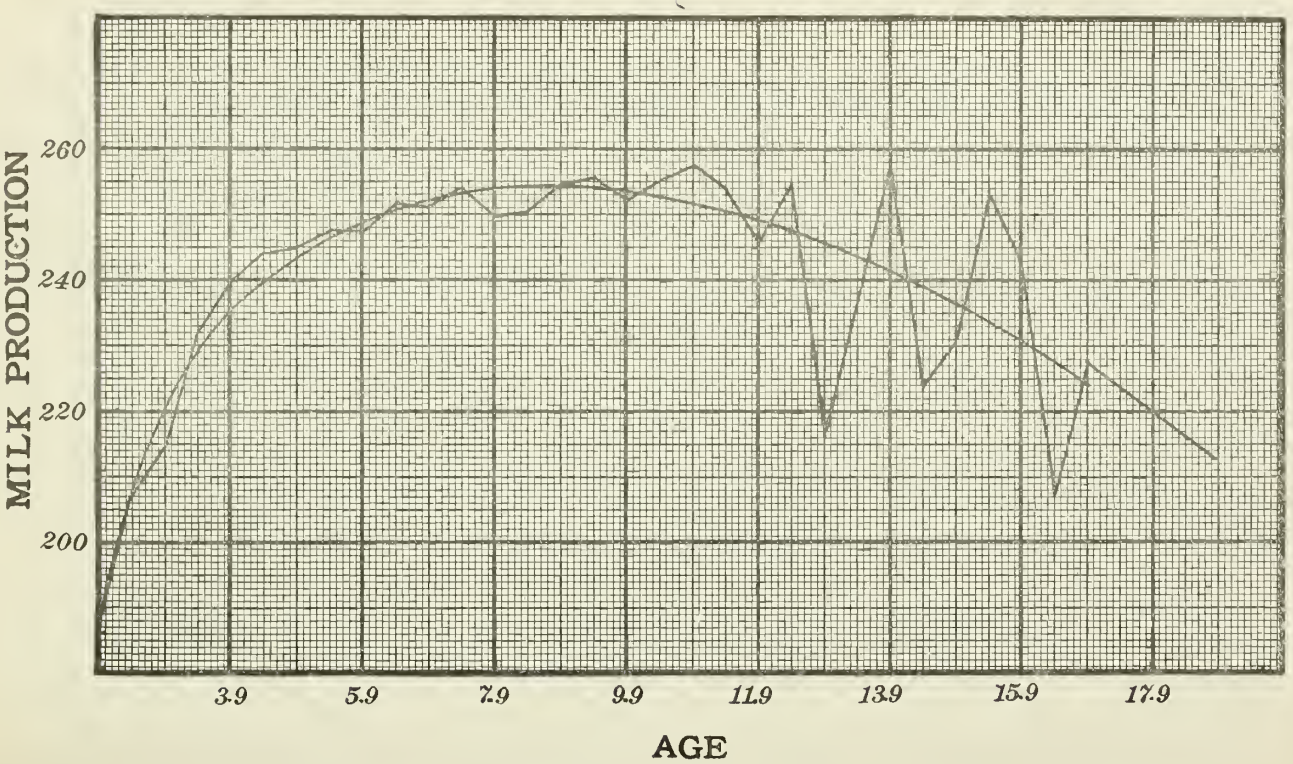

Figure 7. Observed and theoretical curves of milk production (7 day) at various ages in Jersey cows.

The observed curve shows itself at once to have the general shape of a logarithmic curve and not a straight line, as has been the general opinion of dairymen as stated earlier.[3] In graduating this curve the points determined by the coordinates of the first array and the arrays beyond the one whose mid-point is 16 years 9 months should be disregarded because of the paucity of observations in the original table. For the same reason too much weight should not be put on any of the points above 12 years 3 months. The first part of the observed curve, where the frequency of observations is large, is quite smooth and shows well the general type of curve which will best fit.

As a first approximation a curve of the form

$$y = a + bx + cx^2 + d \log x$$

where y=production and x=age was fitted by the observations. The value of the constants a, b, c, and d were determined by the method of least squares. This curve closely fitted the data at the points near the middle of the range, but it failed at the ends. The nature of the discrepancies was such as to indicate that better results would be got by a slight modification of this same general type of curve. This proved to be the case. The final curve, from which the smooth curve of Figure 7 is drawn is

$$y = 188.0224 - .0707\ x^2 + 69.8997 \log x$$

This curve obviously gives a practically perfect fit.

In Table 2 are given the theoretical average seven-day milk production as calculated from this curve for each month in age from 1 year 9 months to 16 years 9 months.

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[3]The fact that milk production age curves were generally of logarithmic form was first announced in a preliminary paper by Pearl (Proc. Soc. Exp. Biol. and Med. Vol. xii, pp. 18-19, 1914.) several years ago. The present paper furnishes the first detailed exhibition of the evidence on which the preliminary announcement was based. It was hoped that a series of several papers would immediately follow this one on the Jersey seven-day records, in which a large mass of evidence from the records of production of other breeds would have been presented. This has been rendered impracticable for the present by the fact that the senior author has been called to wholly other lines of endeavor for the duration of the war. In the meantime attention should be called to the fact that the Holstein-Friesian 7-day fat production curve worked out in this laboratory has been published, but without discussion. (cf. Miner, J. R. Jour. Agr. Research, Vol. 3, pp. 417-420, 1915.).

Table 2.

Mean milk production in 7 days, at each month of the cow's age, Jersey data.

Age in Yrs. and Mos.	Pounds Milk in 7-day Test.	Age in Yrs. and Mos.	Pounds Milk in 7-day Test.
1:9	187.95	5:11	249.67
1:10	192.61	6:0	249.99
1:11	197.62	6:1	250.29
2:0	200.17	6:2	250.58
2:1	203.34	6:3	250.85
2:2	206.18	6:4	251.12
2:3	208.78	6:5	251.37
2:4	211.17	6:6	251.61
2:5	213.35	6:7	251.84
2:6	215.40	6:8	252.06
2:7	217.30	6:9	252.26
2:8	219.07	6:10	252.46
2:9	220.74	6:11	252.64
2:10	222.31	7:0	252.82
2:11	223.78	7:1	252.98
3:0	225.19	7:2	253.14
3:1	226.52	7:3	253.29
3:2	227.77	7:4	253.41
3:3	228.98	7:5	253.54
3:4	230.12	7:6	253.65
3:5	231.21	7:7	253.76
3:6	232.25	7:8	253.85
3:7	233.25	7:9	253.94
3:8	234.20	7:10	254.02
3:9	235.10	7:11	254.09
3:10	235.99	8:0	254.15
3:11	236.83	8:1	254.20
4:0	237.64	8:2	254.25
4:1	238.41	8:3	254.28
4:2	239.15	8:4	254.31
4:3	239.87	8:5	254.33
4:4	240.56	8:6	254.34
4:5	241.22	8:7	254.35
4:6	241.85	8:8	254.34
4:7	242.47	8:9	254.33
4:8	243.06	8:10	254.31
4:9	243.63	8:11	254.28
4:10	244.18	9:0	254.25
4:11	244.70	9:1	254.20
5:0	245.21	9:2	254.15
5:1	245.70	9:3	254.10
5:2	246.17	9:4	254.03
5:3	246.62	9:5	253.96
5:4	247.06	9:6	253.88
5:5	247.48	9:7	253.80
5:6	247.88	9:8	253.70
5:7	248.27	9:9	253.61
5:8	248.64	9:10	253.50
5:9	249.00	9:11	253.39
5:10	249.34	10:0	253.27

Age in Yrs. and Mos.	Pounds Milk in 7-day Test.	Age in Yrs. and Mos.	Pounds Milk in 7-day Test.
10:1	253.14	13:5	243.07
10:2	253.01	13:6	242.70
10:3	252.87	13:7	242.33
10:4	252.72	13:8	241.95
10:5	252.57	13:9	241.57
10:6	252.41	13:10	241.18
10:7	252.24	13:11	240.78
10:8	252.07	14:0	240.38
10:9	251.89	14:1	239.98
10:10	251.71	14:2	239.57
10:11	251.52	14:3	239.15
11:0	251.32	14:4	238.73
11:1	251.12	14:5	238.31
11:2	250.91	14:6	237.88
11:3	250.69	14:7	237.44
11:4	250.47	14:8	237.00
11:5	250.25	14:9	236.55
11:6	250.01	14:10	236.10
11:7	249.77	14:11	235.67
11:8	249.53	15:0	235.18
11:9	249.28	15:1	234.72
11:10	249.02	15:2	234.25
11:11	248.76	15:3	233.77
12:0	248.49	15:4	233.29
12:1	248.22	15:5	232.80
12:2	247.94	15:6	232.31
12:3	247.65	15:7	231.81
12:4	247.36	15:8	231.31
12:5	247.06	15:9	230.81
12:6	246.76	15:10	230.29
12:7	246.45	15:11	229.78
12:8	246.14	16:0	229.26
12:9	245.82	16:1	228.73
12:10	245.49	16:2	228.20
12:11	245.17	16:3	227.66
13:0	244.83	16:4	227.12
13:1	244.49	16:5	226.58
13:2	244.14	16:6	226.03
13:3	243.79	16:7	225.47
13:4	243.43	16:8	224.92
		16:9	224.35

SUMMARY

1. Milk production changes with age in a definite manner.

2. This change follows a logarithmic curve of the form $y=a+bx^2+c \log x$ where y=production and x=age.

3. Maximum production is reached at approximately the age of 8 years and 7 months.